PB-217 858

WATER QUALITY CONTROL STUDY AND PUBLIC HEALTH ASPECTS OF THE WEST DIVIDE PROJECT COLORADO: STUDY OF POTENTIAL NEEDS AND VALUE OF WATER FOR THE PURPOSE OF WATER QUALITY CONTROL AND THE PUBLIC HEALTH ASPECTS OF THE WEST DIVIDE PROJECT, COLORADO

Public Health Service
Denver, Colorado

October 1964

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WATER QUALITY CONTROL STUDY
and
PUBLIC HEALTH ASPECTS
of the
WEST DIVIDE PROJECT
COLORADO

LOCATION MAP

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U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE, REGION VIII
DENVER, COLORADO

OCTOBER 1964

HE 20.2: U.S. HEW
Public Health Service
General Publ cations

W 52 Water quality control study and public health aspects of West Divide project, Colo. [with list of references]. Oct. 1964 (Region 8, Denver, Colo.)[Prepared at the request and in cooperation with Bureau of Reclamation, Region 4, Dept. of Interior, Salt Lake City, Utah.] Environmental Protection Agency

(no LC number)

WATER QUALITY CONTROL STUDY
and
PUBLIC HEALTH ASPECTS
of the
WEST DIVIDE PROJECT
COLORADO

Study of potential needs and value of water for the purpose of water quality control and the public health aspects of the West Divide Project, Colorado

Prepared at the request of and in cooperation with the Bureau of Reclamation, Region 4, U. S. Department of the Interior, Salt Lake City, Utah

U. S. Department of Health, Education, and Welfare
Public Health Service
Division of Water Supply and Pollution Control
Region VIII
Denver, Colorado

October 1964

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INTRODUCTION

Request and Authority

The Bureau of Reclamation, Region 4, Department of the Interior, in a letter dated August 14, 1962, requested the Public Health Service, Department of Health, Education, and Welfare, to participate in the Bureau's project planning as set forth in Section 2(b) of the Federal Water Pollution Control Act (Public Law 84-660, as amended by Public Law 87-88). Further, in accordance with a memorandum of understanding dated September 28, 1956, between Region 4 of the Bureau of Reclamation and the Public Health Service, consideration has been given to the general public health aspects of the Bureau of Reclamation West Divide Project.

Purpose and Scope

General objectives of the water quality control study are to assess the probable effects the proposed project will have on water quality in local streams and reservoirs; to ascertain the benefits or harm resulting from changes in water quality; to assess the suitability of the water for proposed water uses; and to examine the need for regulation of streamflow for the purpose of water quality control. The need for streamflow regulation was studied not only for the present conditions, but also for anticipated future conditions in the West Divide Project area for the years 1970, 1985, 2010, and 2060.

Since this study has been made in advance of any comprehensive study of the Colorado River Basin, the findings presented are preliminary and subject to revision upon completion of comprehensive studies for water supply and water quality management in the Colorado River Basin.

The report includes the results of a study of general public health aspects and insect vector control of the project. The insect vector control section, prepared jointly by the Colorado State Department of Public Health and the Communicable Disease Center, Public Health Service, Greeley, Colorado, presents a preliminary evaluation of the insect vector problems that may be associated with the project.

Acknowledgements

The assistance and cooperation of many state and federal agencies and individuals are gratefully acknowledged by the Public Health Service. Particular appreciation is expressed to the following for data and advice furnished by their staff members:

U. S. Bureau of Reclamation, Region 4
Regional Office - Salt Lake City, Utah
Grand Junction Projects Office - Grand Junction, Colorado

Colorado State Department of Public Health
Denver, Colorado

Union Carbide Nuclear Company
Rifle, Colorado

Colorado Department of Game and Fish
Denver, Colorado

U. S. Department of Agriculture
Forest Service and Soil Conservation Service
Denver, Colorado

Valley Landowners Association
Glenwood Springs, Colorado

PART A

WATER QUALITY CONTROL STUDY

SECTION I

SUMMARY OF FINDINGS AND CONCLUSIONS

1. The West Divide Project, located in west central Colorado, will develop waters for irrigation and municipal use for an area south of the Colorado River between Silt and DeBeque, Colorado. A small area north of Carbondale, Colorado, will also receive irrigation water. High mountains, plateaus, and river valleys make up the area; and the climate is semiarid.

2. Areas of population and economic activity are centered in the valleys along the north and east sides of the project lands. Approximately 12,000 people are sparsely settled in the area. Activities include agriculture, mining, and recreation. Agriculture is the most important basic industry in the area in terms of both employment and production. Extensive mineral deposits of oil shale are presently of greatest economic significance.

3. Water quality in the project area varies considerably from the higher elevations to the lower valley areas. Waters found in the mountains are low in mineral concentrations (TDS is approximately 250 mg/l) during most of the year. Water from the geologic formations of the valleys contains a relatively high mineral concentration (TDS is approximately 1400 mg/l). Chemical quality of water in the Colorado River near Rifle varies considerably and requires softening at least eight months out of each year if used for municipal and industrial purposes.

4. Ground water supplies are not significant in the area. From surface sources, the major use of water at present is for irrigation with municipal and industrial water demands being minor. Municipal and most industrial waste discharges are of no significance now, but irrigation return flows and natural sources (i.e. land drainages, warm springs, groundwater) of pollution increase the mineral concentration of surface waters. The industrial discharge of the uranium mill at Rifle, Colorado, will require constant surveillance to prevent a serious problem. Studies are presently underway to determine the adequacy of present waste treatment.

5. The anticipated development of the oil shale industry will radically change the nature of this region generating new activity in mining, retorting, construction and a multitude of associated services. Agriculture will no longer be the most important economic activity. Population is expected to expand rapidly from the sparse 12,017 of 1960 to 229,000 in 1985 and ultimately to 351,000 in 2060, making this the second largest concentration of people in the state of Colorado.

6. The operation of the proposed West Divide Project will increase concentration of total dissolved solids in the Colorado River approximately 6 percent over the average flow weighted concentration of the past 20 years. The effect of this increase is presently undefinable since downstream users are limited mostly to irrigators. Organic waste loadings as projected from the expected oil shale development will be adequately assimilated by the after-project streamflows in the Crystal, Roaring Fork, and Colorado Rivers. Any future water resources developments upstream of this project will require a re-evaluation as to the cumulative deterioration of water quality downstream.

7. Based on information available, there is no need foreseen for inclusion of storage in the project reservoirs for regulation of streamflow for the purpose of water quality control.

SECTION II

DESCRIPTION OF THE PROJECT AND THE PROJECT AREA

Proposed Project Development[1/]

The West Divide Project may be described as follows:

1. Yank Creek Reservoir in the Thompson Creek drainage will store waters for irrigation of a small area (4065 acres) west of Carbondale, Colorado.

2. The Placita Reservoir will store water from the Crystal River for transmission to lands south of the Colorado River between Silt and DeBeque via Huntsman Conduit, West Divide Creek, and a series of new canals. This water will be used for full and supplemental irrigation and for municipal and industrial purposes.

3. Haystack Reservoir in the West Divide Creek drainage will provide water during peak irrigation demand to supplement the capacity of Huntsman Conduit.

4. Grass Mesa and Morrisania Reservoirs will store water for municipal and industrial use.

The project will develop waters principally for irrigation and municipal use. Flood control, fishery enhancement, and recreation are secondary objectives of the project. A pullout map of the area is provided at the end of this report (Figure 1).

Description of the Project Area

The proposed West Divide Project is located in west central Colorado and includes approximately 770 square miles. This area lies in the counties of Pitkin, Garfield, Mesa, and Gunnison and is included in the West Divide Water Conservancy District. The project encompasses parts of three river basins: the Crystal River, the Roaring River, and the the Colorado River. Boundaries of the project area include the Crystal and Roaring Fork Rivers on the east, the Colorado River on the north, and Battlement Mesa and Horsethief Creek on the south and west.

The area consists of high plateaus and mesas separated by deep erosional channels and valleys bordered by river terraces and alluvial slopes. Elevations range for project lands from over 8000 feet along the southern boundary to about 4900 feet at DeBeque, Colorado. Glenwood Springs, located just outside the eastern boundary of the project area, is of interest because of its past influence on the economic development of the project area.

Major geologic materials in the area consist of the tertiary deposits of Wasatch and Green River formations. Although not extensive, quaternary deposits consisting mainly of alluvium and terrace deposits are confined principally to the stream channels and flood plains. The Green River shale formation, deposited as bottom sediments in lakes 50 to 75 million years ago, contains valuable hydrocarbon deposits which can be transformed into oil. The Wasatch formation, on which the major portion of the project lands are located, generally contains high sodium and saline members which add to the concentrations of the water draining through these formations.

The alluvium deposits along the stream channels and flood plains of the Colorado River Valley were developed from the Wasatch and Green River formations. The mesa and benchland soils of the Wasatch and Green River formations on the south side of the Colorado River make up a major portion of the West Divide Project lands. The natural vegetation consists mainly of pine, fir, oak, and aspen at the higher elevations and juniper, big sagebrush and grasses at the lower elevations. Soil erosion problems may be significant particularly on the steeper slopes of the elevated mesas.

The climate of the study area is considered semiarid and generally satisfactory for diversified agriculture. The frost-free period averages about 140 days at Glenwood Springs and about 142 days at Rifle.[2/] Precipitation averages about nineteen inches annually at Glenwood Springs and about eleven inches annually at Rifle.

SECTION III

THE ECONOMY

Present

Although the geographic boundaries of the West Divide Project include portions of Pitkin, Garfield, Gunnison and Mesa Counties, the major impact of the project will be limited to Garfield County. Since most of the population and economic activity, past and present, has centered in Garfield County and the anticipated future growth is also expected to center here; the economic evaluation for this study has been carried out only within the political boundaries of Garfield County, Colorado.

The general area located toward the western limits of the Colorado Rockies is sparsely settled. Population and economic activity of the area is restricted principally to the valleys along the north and east sides of the project lands. Basic industries include agriculture, recreation, mining, and manufacturing. The agricultural industry contributed much to the early growth and present development. Mining also contributed to early growth, not as a result of mineral exploitation in the area, but because Glenwood Springs served as an intermediate stop for a large part of the supplies and equipment needed by nearby mining districts. The tourist industry (recreation) is presently of considerable importance to the local economy. The study area is the entry point to excellent hunting and fishing areas as well as numerous other recreational activities. The manufacturing industry has been limited generally to meeting the demands of the area's population and local economy.

Based upon data obtained from U.S. Department of Agriculture Colorado River Basin Field Party, it is estimated that the West Divide Project area presently contributes about 33 percent to total county agricultural output. Under future conditions agricultural output of the West Divide Project area is expected to increase to about 50 percent of total county output. Irrigated agriculture is relatively uniform throughout the study area. Non-irrigated agriculture is not considered significant. Agricultural employment has declined steadily since 1940, but still employed 17.1 percent of the total employed labor force in 1960 compared to 11.6 percent in mining and 2.8 percent in manufacturing (Table I). Comparable figures for agriculture in the state of Colorado and the United States in 1960 were 7.7 and 6.7, respectively. Agricultural production centers primarily around livestock and livestock products supported by forage crops and pasture. Some field crops and fruits are produced for market. In 1959, the value of these crops amounted to about $600,000 while livestock and livestock products amounted to about $4,100,000 or 87 percent of the total value of all

TABLE I

POPULATION AND LABOR FORCE TRENDS
BY MAJOR INDUSTRY DIVISION
West Divide Study Area

Industry	1940		1950		1960	
	Number	Percent	Number	Percent	Number	Percent
Agriculture & Forestry	1,529	45.6	1,321	30.1	770	17.1
Mining	81	2.4	231	5.3	523	11.6
Manufacturing	84	2.5	257	5.8	125	2.8
Construction	207	6.2	394	9.0	374	8.3
Transportation, Communications & Utilities	197	5.9	282	6.4	261	5.8
Trades	458	13.7	764	17.4	918	20.4
Services	582	17.4	648	14.8	779	17.3
Government	131	3.9	335	7.6	441	9.8
Finance & Other	82	2.4	157	3.6	310	6.9
Total Employed	3,351	100.0	4,389	100.0	4,501	100.0
Total Unemployed	438		137		347	
Total Labor Force	3,789		4,526		4,848	
Total Population	10,560		11,625		12,017	

Source: U. S. Bureau of the Census

farm products. The number of farms in the study area decreased from 831 in 1944 to 532 in 1959. On the other hand, the average size of farms increased from 509 acres in 1944 to 907 acres in 1959.[3] This trend toward fewer and larger farms reflects state and national trends.

The marketing of agricultural products presents a problem because the major marketing facilities are located 90 miles to the west and about 175 miles across the Continental Divide to the east. This affects farm operating costs; however, both railroad and highway transportation facilities serve the area.

National Forest and Bureau of Land Management lands contribute to the economy of the area largely through livestock grazing and recreational uses. There is some timber harvesting on National Forest lands, but its contribution to the economy of the area is small as is mining activity.

Outdoor recreation and tourism are important factors in the economy of the study area. Dude and guest ranches and resort-type facilities in and near the study area accommodate year-round recreational activities. Glenwood Springs is considered one of the most popular tourist resorts on the Colorado western slope. Visitor counts to the hot springs mineral pool increased from 60,282 persons in 1956 to 125,000 in 1960.[4] Highly developed ski areas at nearby Aspen and Vail draw large numbers of skiers from all parts of the nation. The study area and counties immediately bordering rank among the highest in the state for annual big game harvest.[5] Access to excellent game fishing in both streams and lakes is almost unlimited.

The White River National Forest bordering both the north and south sides of the study area offers an abundance of developed and expanding recreational facilities. Recreational visits to the White River National Forest increased each year from 1956 through 1960 bringing outside dollars into the local economy.[4]

Mineral resources[6] of the area include coal, natural gas, oil shale, base and precious metals, and various construction and chemical materials; however, the value of mineral production in recent years has been relatively small. Coal reserves in the area are extensive and include both bituminous and anthracite coking coal. Current production (near Redstone) is used largely for steam generation; some metallurgical coking coal is being shipped out of the area. Commercial quantities of natural gas are known to exist in the Tertiary, Cretaceous and Jurassic deposits of the study area. Construction materials (sand, gravel and limestone) made up 77 percent of the total value of mineral production in 1962.[7] In addition, extensive deposits of the famous Colorado Yule Marble, gypsum and clay exist in the area. Production of construction materials in 1962 increased by 476 percent over 1960.

Most significant of this area's resources are the vast undeveloped reserves of petroleum locked in the "oil shales" of the Green River formation. The richest reserves are located in the Piceance Creek Basin situated north of the Colorado River near DeBeque and Rifle, Colorado. Oil shale has been produced commercially in other parts of the world, but not as yet in the United States. Current research is expected to make the price of oil shale competetive with that of crude oil within the near future.

Thirty-four manufacturing establishments employed less than 3 percent of the total labor force in 1960 (Table I). Over half of these establishments were engaged in either food processing or production of lumber and wood products.[8/] The Union Carbide Company, nuclear division ore processing plant at Rifle, is classified under mineral industries (miscellaneous metal ores) by the U.S. Bureau of Census and is included with mineral industries for purposes of this report.

Although manufacturing is limited and mostly for the local market, such activities are important to the economic base of the area.

Employment in the retail trades and government has become an increasingly important part of the total labor force. This shift of importance between industries (which is also occuring on a national scale) is perhaps more important than changes in the total volume of employment. The increase in employment in service type industries, in part, reflects the growing importance of the recreational industry to the local economy.

Total population in the study area increased 3.3 percent from 1950 to 1960. This increase was primarily in the two trade centers, Glenwood Springs and Rifle. Population of smaller towns (less than 1000 population) has remained almost constant during the past two decades. Migration estimates show a net outmigration of 1009 persons during the period 1950 to 1960.[9/] The current educational level is below that for the state of Colorado but above the national level. The median years of school completed in 1960 was 11.3, compared to 12.1 for Colorado and 10.5 for the United States. Median family incomes have increased from $2,775 in 1950 to $5,217 in 1960.

Future Growth

Consideration of past economic development is not as important as the effects of new forces and developments which are expected to influence future growth. These new forces are essentially the development of a new industry -- oil shale production on a commercial scale.

Numerous research papers, reports and publications have been developed by private individuals, institutions, companies and organizations, and state and federal agencies concerning the oil shale industry. The studies developed by the Denver Research Institute (DRI), University of Denver, and the following assumptions, were utilized to arrive at the projected conditions.

1. The Nation and the Colorado River Basin will experience a relatively high level of employment, stable prices, and continued development and adoption of technology consistent with the needs of an increasing population.

2. Oil shale will be produced on a commercial scale in northwestern Colorado by 1970-75. Estimated daily production at full capacity operation is expected to average one million barrels per day of partially refined product. The partially refined product would then be transported by pipeline to other marketing areas for refining to finished products.

3. The industrial-urban complex to support the oil shale industry will center near Grand Valley, Colorado.

4. An adequate water supply of suitable quality to support the projected economy will be available.

5. The proposed West Divide Project will play an important role in the area's expanding industrial base due to location and potential water supply developments for irrigated agriculture, municipal and industrial use.

The full impact of an oil shale industry on the economy of the study area is not known nor will it be known until the industry is established. In the initial stages of the oil shale development the growth patterns are expected to follow that experienced in other mining and single-industry cities. Development of additional industries related to by-products will be limited by the distance to the major markets. From the DRI report the National Petroleum Council Committee assumed that mining, retorting and partial refining facilities would be located in Colorado and that the partially refined product would then be transported via pipeline to the Los Angeles, California, area. On this basis, by-products of refining in Colorado would be ammonia, sulfur, coke and fuel gas most of which will be shipped to markets outside the area. The DRI report further developed estimates of production, employment and income as follows: "Based on crude shale oil production capacity of 1,000,000 barrels per calendar day (B/CD), the facilities would produce the following quantities of petroleum derivatives:

In California Facilities		In Colorado Facilities	
Gasoline (B/CD)	502,600	Gasoline (B/CD	5,000
Diesel Oil (B/CD)	249,440	Ammonia (tons/CD)	1,840
LP Gas (B/CD)	35,680	Sulfur (tons/CD)	860
Residual Fuel (B/CD)	12,200	Coke (tons/CD)	23,600
		Fuel Gas (thousand standard cubic feet/CD)	496,600

The bulk of Colorado by-products would be shipped to markets out of the area unless and until by-product industries were located in the area. The personnel requirements to operate and maintain the facilities within Colorado would number 59,130 employees with an annual payroll of $387,120,000."[10/]

Employment projections for the "basic" industries are shown in Table II. Employment in the "non-basic" or "local service" industries as shown in Table II (all other industries) was developed by applying adjusted ratios of "non-basic" to "basic" employment. Ultimate total employment by time periods was derived, and estimated unemployment rates were then applied to determine total labor force. Total population, derived by using adjusted population labor force ratios, is expected to increase from 12,017 in 1960 to 228,700 in 1985 and 351,000 in 2060.

Agriculture is expected to play a minor role in the future economy. Production increases are expected with the expansion or irrigated acreages prior to anticipated industrial expansion. As the oil shale industry develops, large acreages of agricultural land will be converted to other uses, particularly lands within the West Divide Project area. This will consist of a shift to vegetables and other cash crops, as well as dairy farming. However, agricultural employment is expected to remain fairly constant at its present level throughout the projection period.

Additional markets are expected to increase demands for the timber resources of the area. Subsidiary industries, commercial activities, and the government sector will develop as the oil shale industry is developed. The outstanding recreational potential in and near the area is expected to develop and expand with population increases. Access to and within the area must be developed for the movement of people and goods. The construction industry will necessarily be extremely active to provide facilities and housing for thousands of additional people.

The drastic changes in the character and magnitude of activity in the study area as revealed by this economic analysis will have an extremely important impact on the water quality of the local streams. The anticipated increase in waste loadings will become a major parameter in planning for the optimum development of the available water resources.

TABLE II

POPULATION AND EMPLOYMENT, WEST DIVIDE STUDY AREA,
Colorado 1960 and Projections for 1970, 1985, 2010, and 2060

Industry	1960		1970		1985		2010		2060	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Employment Distribution										
Agriculture	770	16.0	550	9.0	700	1.0	1,000	1.0	1,000	1.0
Mining and Manufacturing	648	13.0	1,400	23.0	50,000	55.0	50,000	41.0	47,000	36.0
All Other Industries	3,083	64.0	3,900	63.0	38,050	41.0	66,300	54.0	76,800	59.0
Total Employment	4,501	93.0	5,850	95.0	88,750	97.0	117,300	96.0	124,800	96.0
Unemployed	347	7.0	310	5.0	2,750	3.0	4,900	4.0	5,200	4.0
Total Labor Force	4,848	100.0	6,160	100.0	91,500	100.0	122,200	100.0	130,000	100.0
Total Population	12,017		15,400		228,700		317,700		351,000	

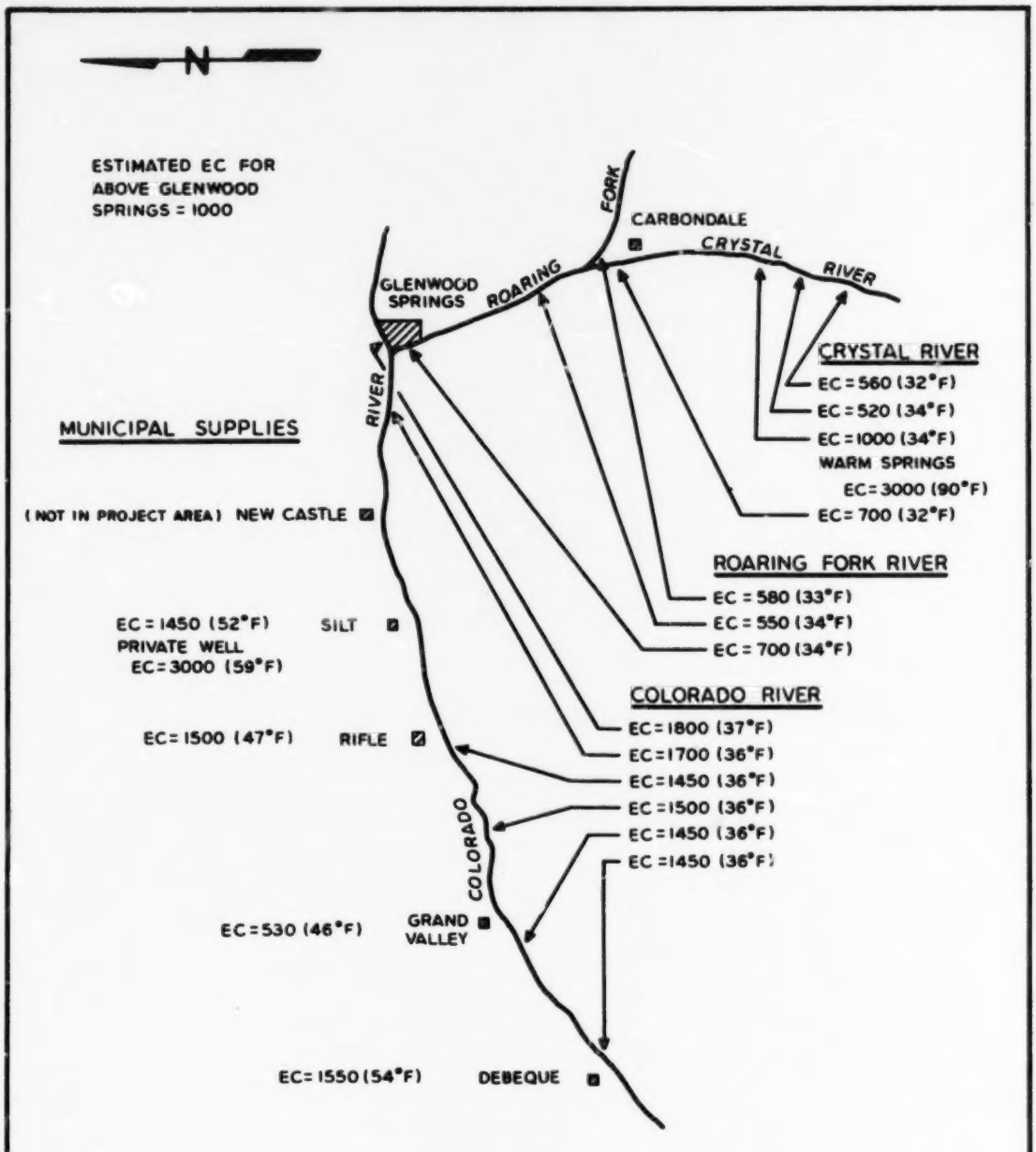
SECTION IV

WATER QUALITY

Surface water which originates in the upper portions of the Crystal and Roaring Fork watersheds generally contain low levels of dissolved minerals and sediment because of the geologic formations that are drained (igneous rock). Water in the lower portions of the Roaring Fork River and that portion of the Colorado River in the project area and its tributaries have varying levels of dissolved minerals, depending upon the geologic formation (in many cases, sedimentary formations) and contain relatively high sediment loads during heavy rains. Impoundments of water in the higher elevations, therefore, will tend to contain a better quality water than is generally found in the lower elevations or valleys.

The variation in water quality in the project area is illustrated in Figure 2. These conductivities and temperatures were obtained for one day during the winter low flow and represent the period of high mineral concentrations found annually. All municipal water supplies shown in the figure come from the Colorado River except for the town of Grand Valley.

Table III gives the maximum and minimum flows and the associated ion concentrations of grab samples collected by the Bureau of Reclamation at various places in the study area. Items 4, 5, and 6 in Table III represent the contribution of the tributaries to the Colorado River from the study area and indicate that these sources of water are marginal (approximately 1500 mg/l TDS) in quality. The data indicate that sulfates and bicarbonates are the major contributors of mineral pollution. While there is little water quality data available for the tributaries south of the Colorado River between Silt and DeBeque, Colorado, there are two USGS water quality stations on the River - above Glenwood Springs and downstream at Cameo. Table IV presents a comparison of the average flow weighted monthly TDS, SO_4, and Cl concentrations at these stations. (Annual weighted averages by flow for various chemical constituents at these two stations are provided in Appendix A.) In some cases the average flow weighted monthly values increase almost 100 percent during the months of low flow. The percentage of cations and anions of sodium and chloride in Table V shows the increase of these constituents between the two USGS stations. The increase in sodium is possibly the result of drainage from the Wasatch formation. The effect of the warm springs at Glenwood Springs on mineralization in the Colorado River is unknown, but it can be assumed that its control during, at least, low flow periods would be beneficial. This is being studied by the Colorado River Basin Project.



EC = SPECIFIC CONDUCTANCE AT 25°C, μ MHOS/CM

WATER QUALITY CONTROL STUDY
WEST DIVIDE PROJECT
WATER QUALITY IN PROJECT AREA ON FEBRUARY 24, 1964 CONDUCTIVITY AND TEMPERATURE

DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VIII DENVER, COLO.

14-B

FIGURE 2

TABLE III

ANALYSIS OF WATER QUALITY BY BUREAU OF RECLAMATION*

Sampling Station (Period) and (Samples)	Max flow** / Min flow (cfs)	TDS (mg/l)	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO_3^{=}$	HCO_3^{-}	Cl^{-}	$SO_4^{=}$
			(milligrams per liter (mg/l))***							
1. Crystal River near Redstone (9/57 - 1/61) (27)	1090	107	25.2	3.4	2.8	0.8	0	72.0	1.4	23
	28	595	117.0	15.7	42.3	4.0	3.0	141.5	2.7	284
2. Roaring Fork River at Mouth (4/60 - 4/62) (23)	4810	125	30.0	3.9	5.3	1.2	0	77.0	4.3	33.5
	317	429	77.6	17.1	28.3	2.4	3.6	131.2	3.1	166.5
3. Colorado River at New Castle (9/60 - 4/62) (17)	7814	232	40.0	11.0	19.8	0.8	4.8	114	26	49.6
	700	621	82.0	21.0	96.0	3.5	9.6	167	139	149
4. West Divide Creek near Mouth (9/59 - 10/60) (12)	60	207	36.0	6.2	19.5	2.0	0	165	4.3	18.6
	0.3	1422	45.4	77.9	33.6	5.9	10.8	416	91	655
West Divide Creek upstream 16 miles (9/57 - 1/61) (10)	300	110	29.0	3.5	6.9	1.2	0	114	1.4	8.1
	0.6	275	31.4	22.1	3.3	3.5	13.5	191	15.6	44.1
West Divide Creek upstream 20 miles (5/58 - 10/60) (10)	98	148	33.4	5.5	13.3	0.8	5.7	132.5	2.1	14.4
	1	262	34.2	12.9	29.2	1.6	8.1	182.5	6.0	29.3
5. Mamm Creek near Mouth (9/59 - 10/60) (12)	10.3	456	44.4	25.4	68.0	3.1	10.0	222.0	13	144
	0.5	1960	72.8	44.4	351	9.6	41.1	742.0	67	789
6. Wallace Creek near Mouth (9/59 - 10/60) (12)	1.0	796	47.6	51.7	128.5	4.3	14.7	232	19.5	34.9
	.05	851	90.0	47.8	112.0	6.7	6.9	362	17.8	32.1

* This data was supplied in milliequivalents and was converted to mg/l for this table
** During this period (estimated by the Bureau of Reclamation)
*** Ion concentrations associated with maximum and minimum flow

TABLE IV

AVERAGE FLOW WEIGHTED CONCENTRATIONS OF TOTAL DISSOLVED SOLIDS, SULFATES, AND CHLORIDES
(mg/l)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Range Apr-Aug	Range Sep-Mar
Colorado River														
Total Dissolved Solids														
Above Glenwood Springs	464	451	433	308	186	161	263	363	443	461	461	450	161-363	433-464
Near Cameo	827	805	770	528	271	210	373	595	737	727	756	802	210-595	727-827
Sulfates														
Above Glenwood Springs	107	100	101	77	37	30	69	95	118	122	118	107	30- 77	95-122
Near Cameo	184	182	182	135	57	43	93	142	172	184	186	187	43-142	172-187
Chlorides														
Above Glenwood Springs	117	111	100	54	18	13	44	67	96	100	97	101	13- 67	96-117
Near Cameo	218	212	198	131	44	33	82	140	187	183	189	209	33-140	183-218

Source: USGS Water Quality Data as compiled by the Colorado River Basin Project for period of record of 1942 to 1958 for Glenwood Springs and 1934-1958 for Cameo, Colorado

TABLE V

PERCENT CATIONS AND ANIONS FOR THE COLORADO RIVER AT GLENWOOD SPRINGS AND CAMEO

	Cations			Anions		
	Ca	Mg	Na	HCO_3	SO_4	Cl
Colorado River above Glenwood Springs						
Maximum	92%	59%	95%	76%	87%	37%
Minimum	5%	0%	4%	11%	18%	3%
Average	47%	11%	42%	45%	31%	24%
Colorado River at Cameo						
Maximum	67%	52%	65%	73%	41%	43%
Minimum	20%	4%	21%	27%	16%	9%
Average	37%	9%	53%	39%	30%	31%

Source: USGS Water Quality Data as compiled by the Colorado River Basin Project for period of record of 1942 to 1958 for Glenwood Springs and 1934-1958 for Cameo, Colorado

Water quality has a great economic significance in the development of an area because of its possible limitations on potential use and the degree of treatment required to obtain a desirable quality. An inspection of the available data reveals that the water stored in Placita Reservoir will be of suitable quality for both present and projected water users (i.e. municipal, most industrial, and irrigation). The Crystal River which supplies Placita Reservoir has, at times, high concentrations of sulfates, however, mixing in the proposed reservoir will result in lower concentrations in the outflows than in the corresponding inflows for low quality inflow months. Quality data is not available for flows that will be stored in Yank Creek Reservoir. However, no water quality problems are expected as this water comes from high mountain country (8,000 elevation) and should be of good to excellent quality. The upper reaches of Mamm Creek and West Divide Creek have TDS values of approximately 250 mg/l, but near the Colorado River these values increase to 1500-2000 mg/l during periods of the year limiting the use of these waters mainly to irrigation.

The most dependable water source, from a quantity standpoint in the area, is the Colorado River; however, the quality is highly variable and softening will be required during eight months out of a year. Total dissolved solids below Glenwood Springs range from 210 to 827 mg/l. TDS concentration below 500 mg/l is desirable for a municipal water supply.[11/] Calcium and magnesium hardness in the Colorado River ranges from 150 to 250 mg/l. This causes boiler scale, pipe and water heater deterioration, and increased use of soap. High concentrations of sodium in this area can result in foaming in boilers. Municipalities and industries utilizing the Colorado River as a raw water supply much provide adequate water treatment facilities to remove excessive concentrations of various minerals and thus reduce the damages caused by excessive hardness. Sulfates and chlorides in the Colorado River increase significantly (Table IV) from above Glenwood Springs to Cameo. Although present concentrations of chlorides are not harmful, taste problems may be experienced. Sulfates combine with the constituents of hardness and form scale in boilers.

If the water from Placita Reservoir is not degraded in transmission, it will have a considerable economic advantage over water from the Colorado River in the elimination of softening costs.

SECTION V

WATER SUPPLY AND POLLUTION SOURCES

Major water users and their respective sources are shown in Figure 3. The town of Rifle must supplement their Beaver Creek water supply with water from the Colorado River which is more costly and of a poorer quality. Grand Valley uses spring water, but this source satisfies only a small demand. The unsuitability of ground water as a source is due to poor quality and limited quantity.

Except for Rifle, municipal and industrial water use is not extensive in the project area. In Rifle water is used for domestic, commercial, and industrial (Union Carbide Nuclear Mill) purposes. The oil shale development pilot plant near Rifle has a complete water treatment plant, including softening, adjacent to the Colorado River.

With the increased activity associated with oil shale development the per capita water use is expected to increase from the present 180 gallons per capita per day (gpcd) to a range of 225-275 gpcd. This increase will be associated with a more highly developed economy and greater use of water for lawns and gardens. Agricultural irrigation is presently the largest consumptive water use in this area and will increase under project conditions. Instream uses for the project area include boating and fishing. Fishing, for the most part, is centered in the higher elevations because of the more scenic mountains, while the Colorado River is fished mostly by the local inhabitants.

Water pollution in the West Divide Project area is largely a result of irrigation return flows and natural conditions (i.e. land drainage, warm springs). Figure 4 depicts the known waste sources and the type of treatment provided before discharge. At Glenwood Springs there are a number of warm springs which are used commercially for swimming pools and baths. The discharge from these springs adds to the mineral loading in the Colorado River. The Glenwood Springs sewage treatment plant is presently undergoing modifications. The tributaries from Glenwood Springs to DeBeque contain high mineral concentration; these result from irrigation return flows and natural geologic conditions. Two tailings piles of the Union Carbide Nuclear Company are adjacent to the Colorado River. These tailings are a potential problem in heavy rainfall or floods if not properly cared for. Radiological pollution from this mill has not been a problem in the past, but continuing surveillance to prevent problems from these wastes is necessary. Currently studies are being made to determine the adequacy of the present treatment.

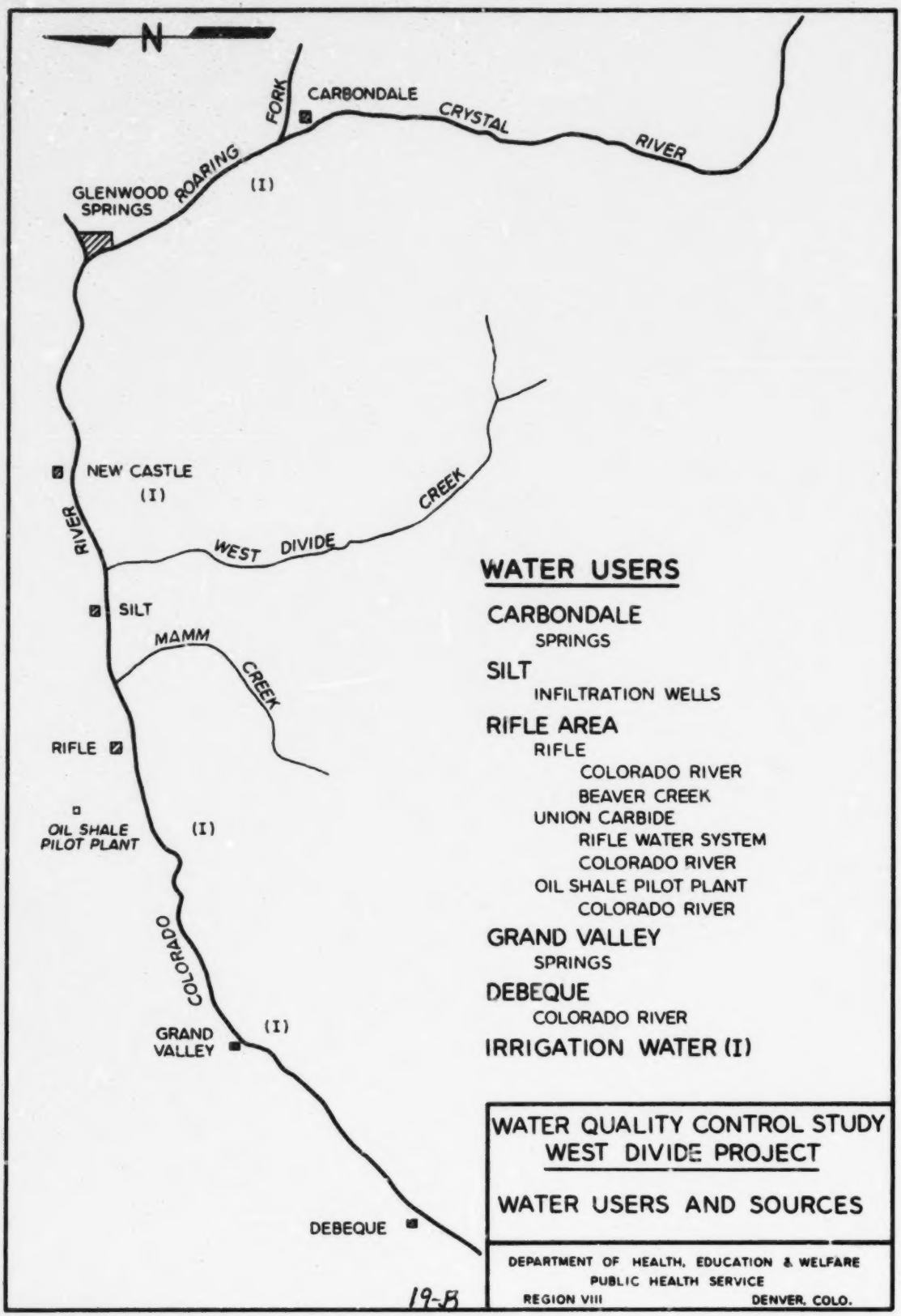

N
CARBONDALE
ROARING FORK
CRYSTAL RIVER
(I)
GLENWOOD SPRINGS
NEW CASTLE
(I)
RIVER
WEST DIVIDE CREEK
SILT
MAMM CREEK
RIFLE
OIL SHALE PILOT PLANT
(I)
COLORADO
GRAND VALLEY
(I)
DEBEQUE
19-B
WATER USERS
CARBONDALE
SPRINGS
SILT
INFILTRATION WELLS
RIFLE AREA
RIFLE
COLORADO RIVER
BEAVER CREEK
UNION CARBIDE
RIFLE WATER SYSTEM
COLORADO RIVER
OIL SHALE PILOT PLANT
COLORADO RIVER
GRAND VALLEY
SPRINGS
DEBEQUE
COLORADO RIVER
IRRIGATION WATER (I)
WATER QUALITY CONTROL STUDY
WEST DIVIDE PROJECT
WATER USERS AND SOURCES
DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VIII
DENVER, COLO.

FIGURE 3

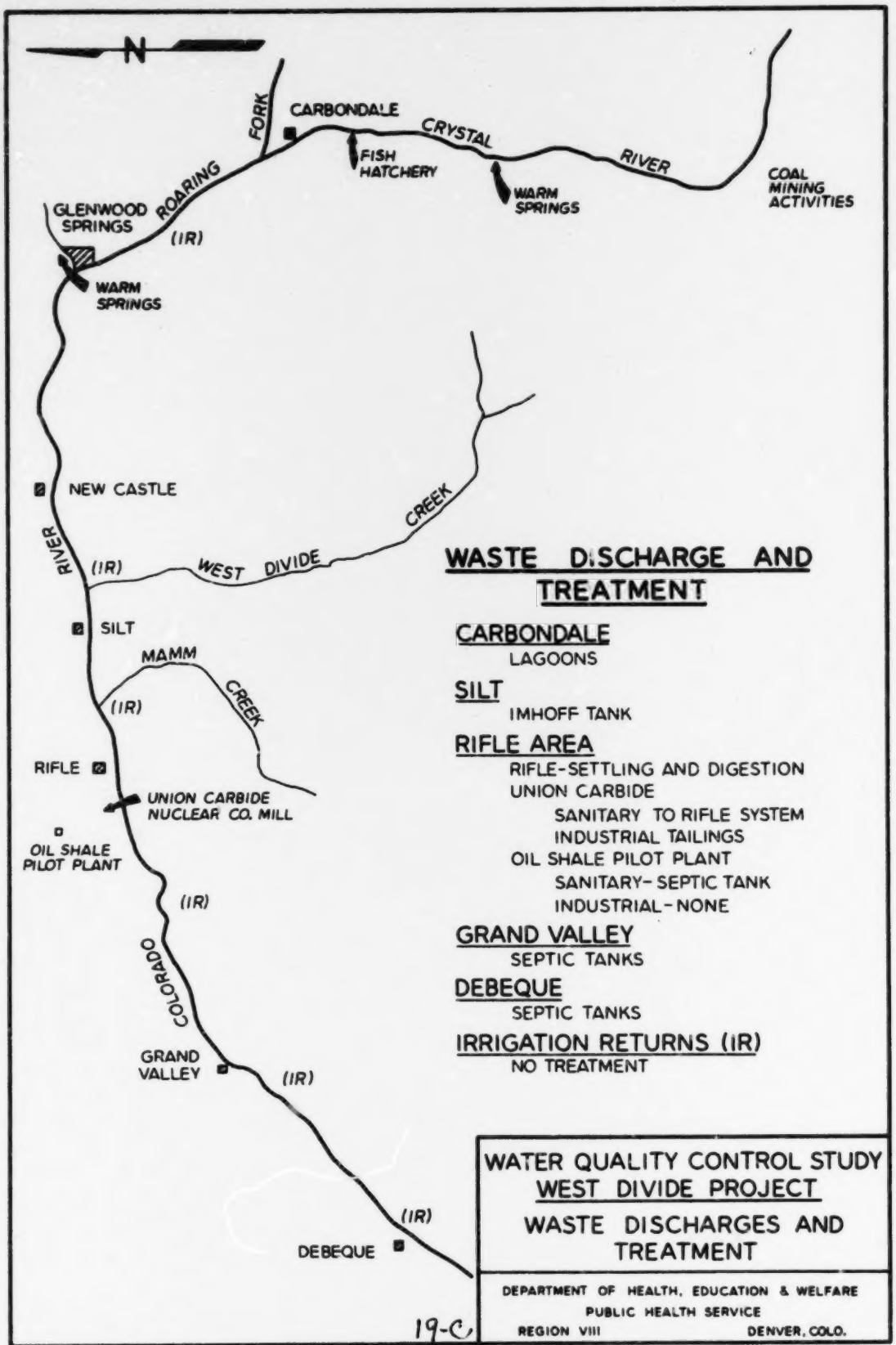

N
CARBONDALE
FORK
ROARING
CRYSTAL
RIVER
FISH HATCHERY
WARM SPRINGS
COAL MINING ACTIVITIES
GLENWOOD SPRINGS
(IR)
WARM SPRINGS
NEW CASTLE
RIVER
CREEK
(IR)
WEST DIVIDE
SILT
MAMM
CREEK
(IR)
RIFLE
UNION CARBIDE NUCLEAR CO. MILL
OIL SHALE PILOT PLANT
(IR)
COLORADO
GRAND VALLEY
(IR)
(IR)
DEBEQUE
WASTE DISCHARGE AND TREATMENT
CARBONDALE
LAGOONS
SILT
IMHOFF TANK
RIFLE AREA
RIFLE-SETTLING AND DIGESTION
UNION CARBIDE
SANITARY TO RIFLE SYSTEM
INDUSTRIAL TAILINGS
OIL SHALE PILOT PLANT
SANITARY- SEPTIC TANK
INDUSTRIAL- NONE
GRAND VALLEY
SEPTIC TANKS
DEBEQUE
SEPTIC TANKS
IRRIGATION RETURNS (IR)
NO TREATMENT
WATER QUALITY CONTROL STUDY
WEST DIVIDE PROJECT
WASTE DISCHARGES AND TREATMENT
DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VIII
DENVER, COLO.
19-C

FIGURE 4

SECTION VI

EFFECT OF PROJECT OPERATION

The Bureau of Reclamation has estimated a depletion in the Colorado River at Cameo of approximately 63,000 acre-feet. While the depletion in the Crystal and Roaring Fork Rivers is mostly the result of transbasin diversion, the depletion in the Colorado River at Cameo is largely from evapotranspiration. Associated with this reduction in flows will be an increase in mineral concentrations. Using available data and on the basis of a salt balance in the irrigated areas, the anticipated increase in TDS for the Colorado River at Cameo was computed as shown by Figure 5. The annual average flow weighted TDS values in the Colorado River at Cameo will increase 6 percent. The effect of this increase is undefinable at this time because of limited demand for water use (municipal and industrial) downstream. When the effect of this project is considered with the possible increases in TDS resulting from flow depletion associated with potential upstream projects, the overall increase in TDS at Cameo may become more significant. However, the evaluation of this overall change in TDS as the result of future projects can only be determined by a comprehensive study approach.

Water from Placita Reservoir will have a hardness of 85 mg/l and the effect of the project area on this water will be to increase mineral concentrations. At present, the hardness in the Colorado River averages (flow weighted) 258 mg/l and under project conditions this average is estimated as 276 mg/l. Estimated changes in hardness associated with project operation are shown in Figure 6 for the Colorado River at Cameo.

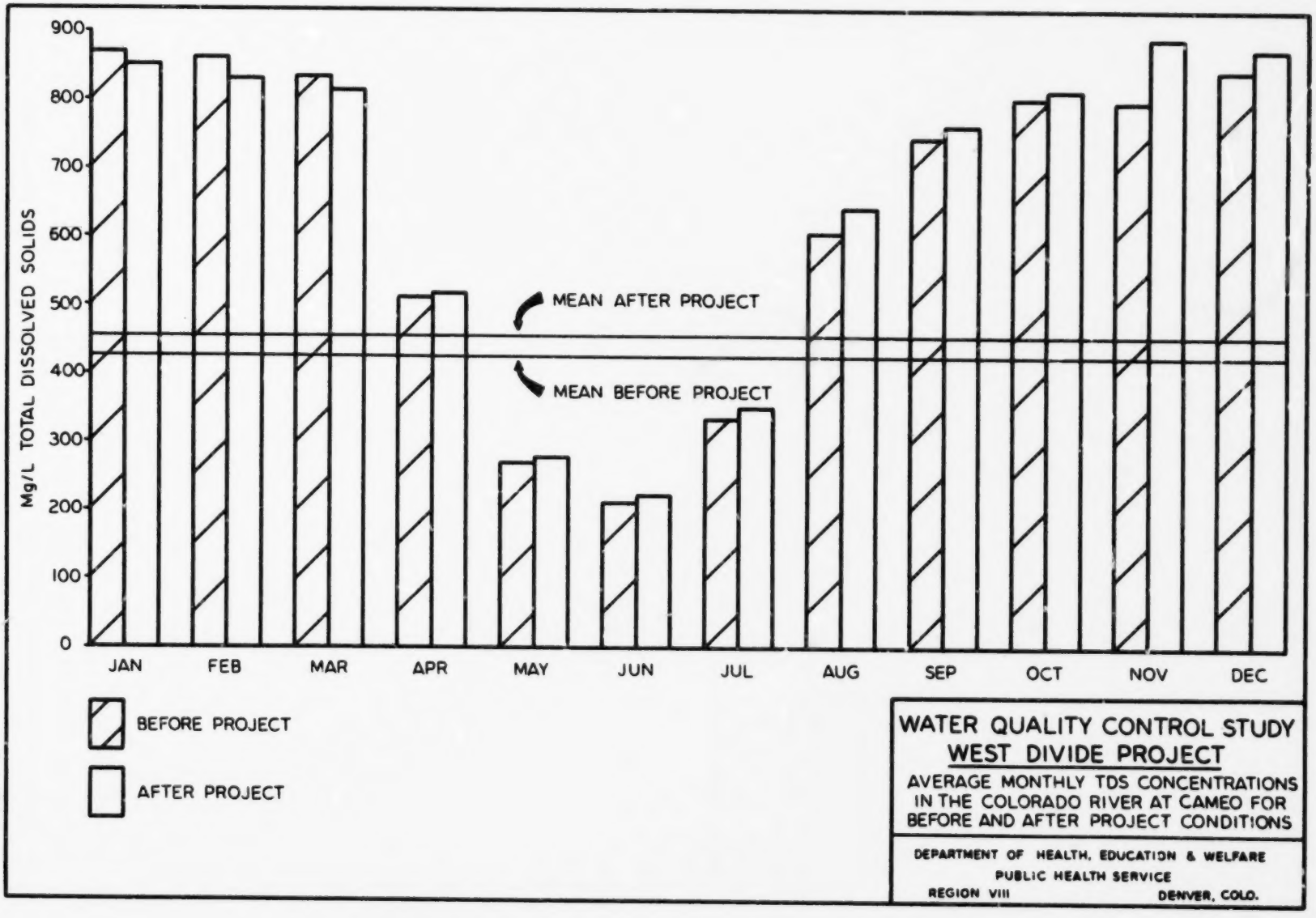
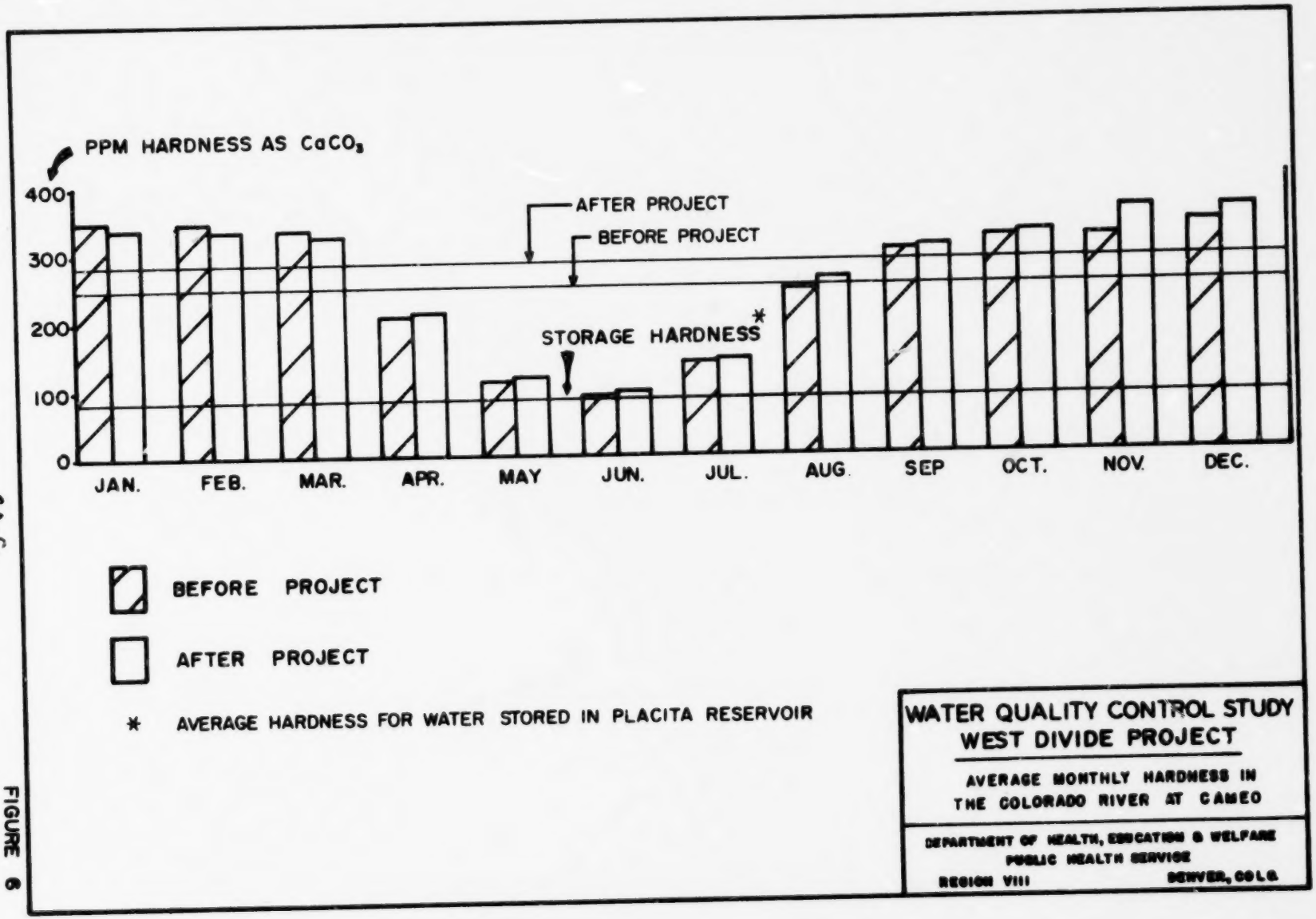

900
800
700
600
500
400
300
200
100
0
Mg/L TOTAL DISSOLVED SOLIDS
MEAN AFTER PROJECT
MEAN BEFORE PROJECT
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
BEFORE PROJECT
AFTER PROJECT
WATER QUALITY CONTROL STUDY
WEST DIVIDE PROJECT
AVERAGE MONTHLY TDS CONCENTRATIONS IN THE COLORADO RIVER AT CAMEO FOR BEFORE AND AFTER PROJECT CONDITIONS
DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VIII
DENVER, COLO.

FIGURE 5


PPM HARDNESS AS $CaCO_3$
400
300
200
100
0
AFTER PROJECT
BEFORE PROJECT
STORAGE HARDNESS *
JAN.
FEB.
MAR.
APR.
MAY
JUN.
JUL.
AUG.
SEP
OCT.
NOV.
DEC.
BEFORE PROJECT
AFTER PROJECT
* AVERAGE HARDNESS FOR WATER STORED IN PLACITA RESERVOIR
WATER QUALITY CONTROL STUDY
WEST DIVIDE PROJECT
AVERAGE MONTHLY HARDNESS IN
THE COLORADO RIVER AT CAMEO
DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VIII
DENVER, COLO.

20-C

FIGURE 6

SECTION VII

MINIMUM FLOW REQUIREMENTS

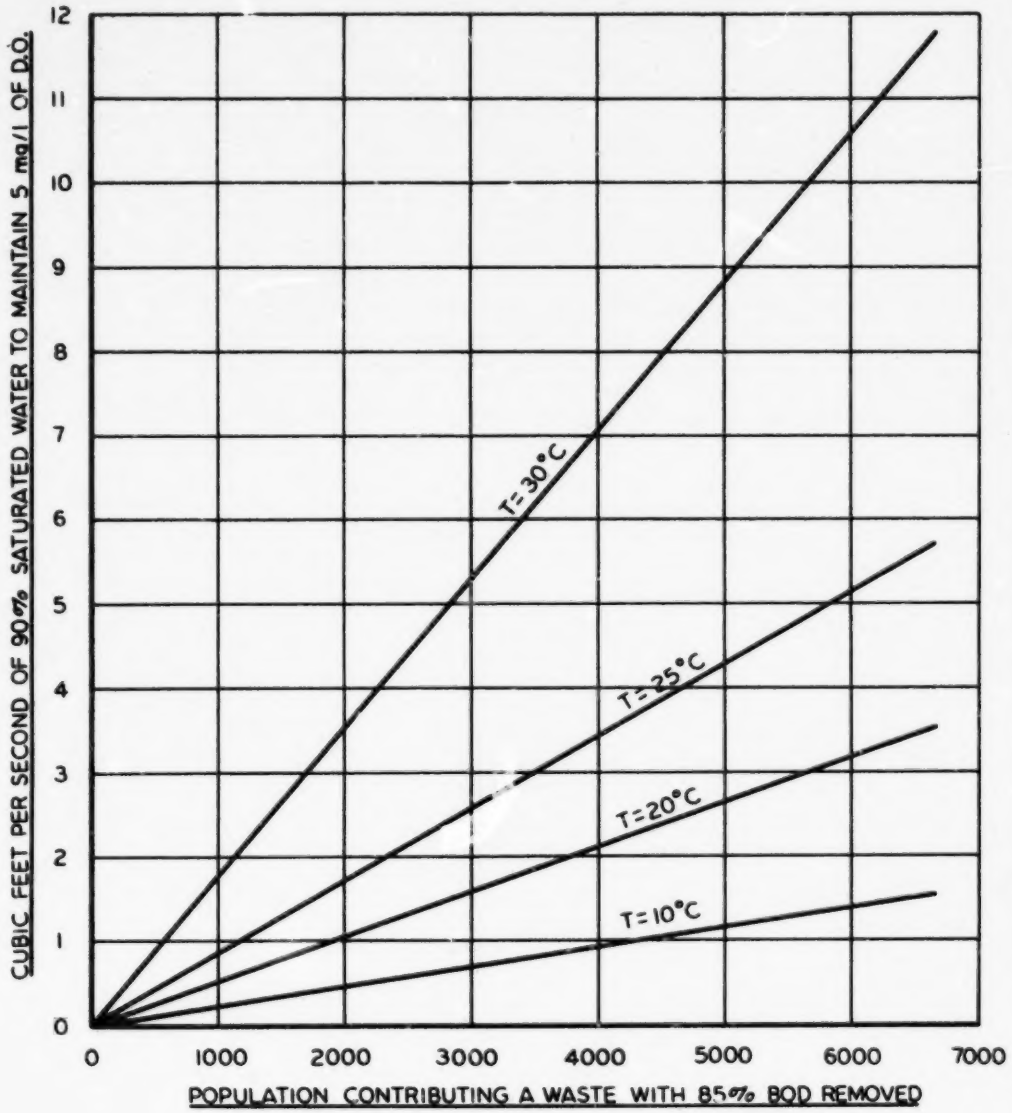
Under provisions of the Federal Water Pollution Control Act, Public Law 84-660, as amended by Public Law 87-88, in the survey or planning of a reservoir by any federal agency, consideration must be given to the inclusion of storage for regulation of streamflow for the purpose of water quality control. It is expressly stated that any such storage and water releases shall not be provided as a substitute for adequate treatment or other method of controlling wastes at their sources. Adequate treatment of wastes as used in this study reflects 85 percent removal of the 5-day, 20°C BOD prior to discharging of waste effluents to surface waters.

Economic activity and future growth in the project area will produce changes in stream characteristics and water quality. This requires a determination of the streamflow necessary to maintain water quality and aquatic life. Discharge of wastes, even when treated to maximum practical limits, will cause an unsatisfactory quality condition when the waste assimilation capacity of receiving waters is exceeded. This condition generally occurs during periods of low flows and warm temperatures and may be avoided by the provision of additional dilution water. It is essential that recognition be given to the need for flows which must prevail in receiving streams if the quality of their waters is to be maintained at acceptable levels.

Water quality as measured by mineral concentrations will be altered somewhat by the proposed West Divide Project. The average annual increase of 6 percent in TDS in the Colorado River at Cameo is not expected to push the concentrations above the salt tolerance limits of the crops presently grown in the area around Grand Junction. Crops grown in this area are predominately high value crops and the projected increase in TDS should not result in damages or in a measureable increase in demand for water required for leaching out the salts.

Maintaining dissolved oxygen (DO) in the major water courses to sustain game fish and aquatic habitat depends on the organic loadings discharged. It is accepted that 5 mg/l of DO as a minimum for short periods[22/] will support game fish, and this figure was used in calculating required minimum flows for organic load assimilation. Calculations have been made using the population projections and future streamflow conditions to determine minimum flows.

For the Crystal River, Carbondale is the only population center and its sewage can be discharged to either the Crystal or Roaring Fork Rivers. Figure 7 shows the flows necessary to assimilate the treated waste (85 percent BOD removal) from various populations for different



NOTES:

K_1 at 20°C = 0.1

f at 20°C = 4.0

ELEV. = 7000'

VOLUME OF WASTE NEGLIGIBLE

WATER QUALITY CONTROL STUDY
WEST DIVIDE PROJECT

DILUTION WATER REQUIREMENTS FOR WASTE FROM CARBONDALE

DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VIII DENVER, COLO.

21-B

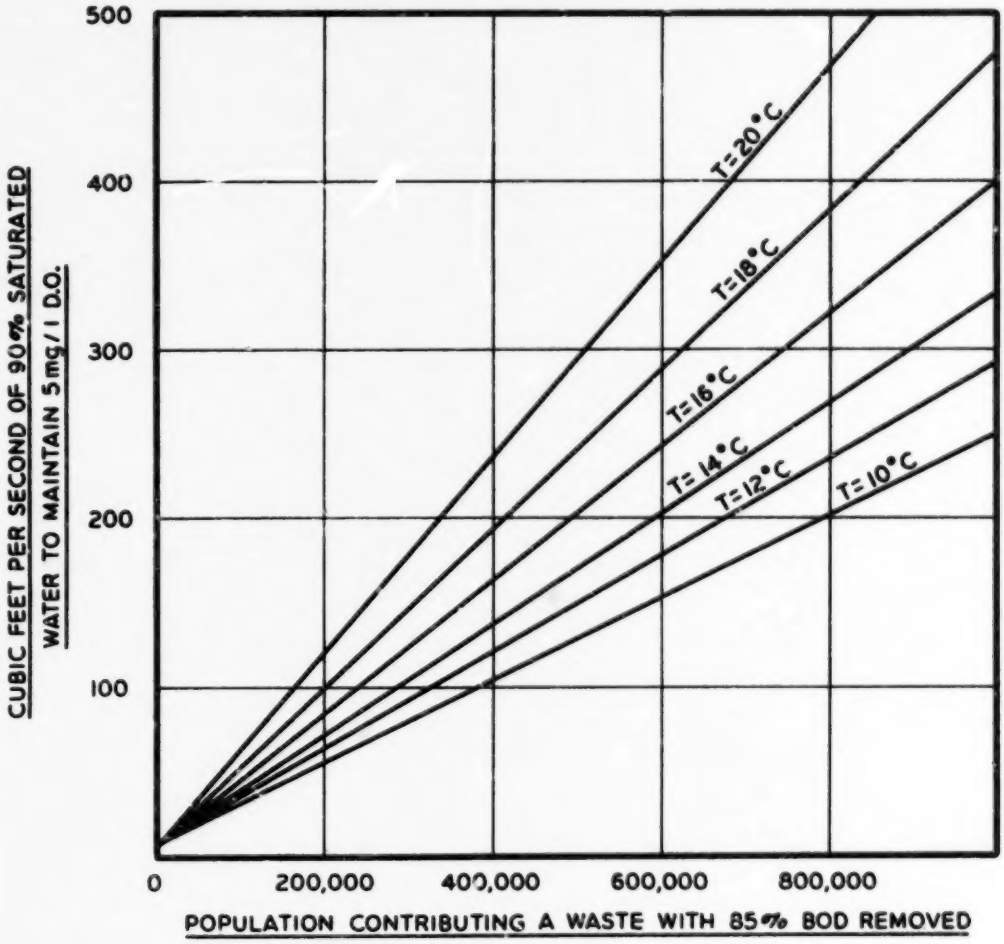
FIGURE 7

water temperatures. The minimum average monthly flow, after project construction, for the Crystal River amounts to 20 cubic feet per second. This exceeds the maximum required flow for the assimilation of Carbondale's domestic waste (assuming a maximum population of 6000) as taken from Figure 7. The flow in the Roaring Fork River exceeds 100 cfs.

Mineral concentrations will increase somewhat in the Crystal River, but will not effect present or forseeable water users. Storage of water for the purpose of water quality control in the Crystal River is not necessary at this time.

Domestic waste discharges associated with the anticipated oil shale development along the Colorado River have been considered as entering the Colorado River at DeBeque. Figure 8 shows the necessary flows for assimilation of treated wastes for various levels of population and water temperature. Flows in the Colorado River, as provided in the Bureau of Reclamation operation study, indicate an average monthly minimum of 1100 cfs or a daily minimum of 700 cfs which exceeds the 210 cfs needed for a population of 350,000 with the water at 20°C. Based on current knowledge of the oil shale processes, it is not anticipated that a pollution problem will arise. Assuming a production of 1,000,000 barrels of crude oil per day (partial refining) a BOD loading of 21,000 PE[23] would be imposed on the river after secondary treatment. This loading would require flows of 70 cfs for assimilation. Combining the projected municipal and industrial waste loadings of 2060, the minimum flows necessary in the Colorado River to assimilate these treated wastes (85 percent removal of BOD) amount to 280 cfs. Monthly average streamflow in the Colorado River as projected for after project conditions is 700 cfs and is adequate to assimilate the treated wastes that are anticipated. Therefore, based on information available, there is no need for streamflow regulation for the purpose of water quality control in the Bureau of Reclamation's West Divide Project.

The West Divide Project is part of the Colorado River Basin. Since this study has been made in advance of any comprehensive study of the Colorado River Basin, the findings, presented in this report are preliminary and subject to revision upon completion of comprehensive studies for water supply and water quality management for the Colorado River Basin.



NOTES:

K_1 at 20°C = 0.1

PE INCOMING at 20°C = 5100

ELEV. = 7000'

WATER QUALITY CONTROL STUDY
WEST DIVIDE PROJECT
DILUTION WATER REQUIREMENTS FOR WASTE FROM PROJECTED POPULATION NEAR GRAND VALLEY, COLORADO

DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VIII DENVER, COLO.

22-B

FIGURE 8

PART B

PUBLIC HEALTH ASPECTS

I. SUMMARY AND RECOMMENDATIONS

Summary

1. Project development will improve the economy and permit the establishment of a more healthful environment. Public health services are provided by the Mesa County Health Department in Mesa County and by the Colorado State Department of Public Health in the remainder of the project area.

2. Recreational development contiguous to reservoirs will be partially regulated by the topographical features of the shoreline.

3. Temporary construction camps may be necessary to serve the contractor's employees.

4. As overall watershed management involves many interests, it is essential that the effect on public health be fully coordinated with state and/or local health departments.

5. Mosquitoes are the principal vectors which might be affected by the proposed project, although other insects and rodents may be involved.

6. Encephalitis is the most important mosquito-borne disease in the United States and in the proposed project area. Equine encephalitis cases occurred in Mesa County during 13 years of the period 1940 through 1955.

7. Provision for the prevention and control of man-made vector sources will increase the overall benefits of the project.

Recommendations

Overall watershed management requires the cooperation of many interests to assure that development and activities will minimize the potential public health hazards associated with the proposed project. It is recommended that the following be given due consideration in development of the West Divide Project:

1. That the water users' organization (i.e., Water Conservancy District) operating as the general administrative and contracting agency for the project should:

    a. Alert all water users of the potential public health hazards associated with using inadequately treated water for culinary purposes;

b. Exert all possible precaution to exclude sewage effluents and barnyard drainage from project canals, laterals, and drains;

c. Wherever and whenever possible assist the project inhabitants and communities in development of approved water and sewerage facilities;

d. Operate and maintain project facilities in accordance with established criteria.

2. That potential recreational areas be investigated and at least minimum water and sanitary facilities be provided in accordance with Colorado State Department of Public Health.

3. That a sanitary survey of proposed construction campsites be made and all camps be provided with water and sanitary facilities in accordance with Colorado State Department of Health regulations.

4. That recreational activities, at reservoirs utilized as a source of public water supplies, meet the requirements established by the Colorado State Department of Health.

5. That person or persons responsible for a public water supply establish suitable controls over the use of watershed areas tributary to the supply to insure production of raw water meeting the quality requirements established by the Colorado State Department of Health.

6. In order to minimize public health hazards, every possible effort should be made to avoid creating conditions which will increase populations of mosquitoes and other arthropods and rodents of public health importance or result in increased exposure of humans to vectors of both aquatic and terrestrial origin. It is recommended:

   a. That where feasible, the principles and practices for prevention and elimination of mosquito sources associated with irrigation outlined in Appendix D be adhered to in the design, construction, and operation of the proposed project.

   b. Where feasible, the principles and practices for prevention and control of vector problems associated with reservoirs outlined in Appendix E be followed.

II. PUBLIC HEALTH AND RELATED PROBLEMS

Public Health Services

Project development will improve the economy of the area so that local residents benefiting either directly or indirectly will be in a position to enjoy a higher standard of living. Among other necessities, this involves the establishment of a healthful environment. Some of the more important factors in creating such an environment include the development of safe and ample culinary water supplies, proper waste disposal facilities, and insect and rodent control measures.

Public health services are provided in the project area by the Colorado State Department of Public Health.

Recreational Development

Concomitant with the development of water resources comes the increased use of lands adjoining reservoirs for recreational purposes. This presents major problems of sanitation involving those of coordination of the multiple use policy and prevention of water pollution. The extent of recreational development, planned or spontaneous, immediately contiguous to reservoirs will be partially regulated by the topographical features of the shoreline. Also, a receding shoreline during the irrigation season, together with an accumulation of mud deposits above the water level, will create hazardous and undesirable conditions for some water-based recreational activities.

Construction Phase of Project

Limited housing accommodations are available in the vicinity of construction sites in the Crystal River and West Divide Creek Basin to serve the contractor's employees during the construction phase of the project. Under these conditions a temporary construction camp may be necessary. Prior to selection of a campsite a sanitary survey of the proposed area should be made by the State Department of Health or the Public Health Service to assist in solving of problems which may be encountered in connection with the installation of water and sanitary facilities.

Water supplies and sanitary facilities required in connection with temporary construction camps and with permanent housing for reservoir attendants should comply with the requirements of the Colorado State Department of Public Health so as to eliminate potential health hazards.

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Water supplies and sanitary facilities required in connection with temporary construction camps and with permanent housing for reservoir attendants should comply with the requirements of the Colorado State Department of Public Health so as to eliminate potential health hazards.

Sanitary Aspects of Watershed Management

As overall watershed management involves many interests, it is considered essential that proposed developments and activities on watersheds pertaining to public health aspects be fully coordinated with state and/or local health departments. These matters should be mutually considered prior to the actual development of the watershed and issuance of permits.

Adequate and safe water and sanitary waste disposal facilities, in accordance with state and/or local health agency standards, should be provided in public use areas to serve camping, picnicking, and other recreational uses. Water and sanitary facilities for private dwelling sites should also meet the established health standards. The effectiveness of the sanitation program should be evaluated periodically by a detailed sanitary survey in conjunction with laboratory analyses of water samples collected from surface and/or ground water in the watershed.

On reservoirs constructed primarily to serve as a source for a municipal water supply, extreme caution should be exercised in considering recreational use of the reservoir. This also involves the possibility of additional pollution entering the water supply and the matter of aesthetics.

Preliminary Vector Evaluation

Anticipated Effects of the Proposed Project on Vector Problems

Encephalitis is a mosquito-borne disease of public health significance in the general area of the proposed project. Records of the U.S. Department of Agriculture show that equine encephalitis cases occurred in Mesa County during 13 years of the 16-year period 1940 through 1955 for which records are available. Eighty-two cases of human encephalitis were reported in Mesa County from 1952 through 1959.

Extensive surveys of the mosquito fauna of Mesa, Garfield, and Pitkin Counties during the past decade have shown several species of mosquitoes to be prevalent in the general area of the proposed project. These mosquitoes include Culex tarsalis, the common encephalitis vector, and several of the voracious Aedes species including A. vexans, A. nigromaculis, and A. dorsalis. These surveys have shown that mosquito-producing habitats in these counties are primarily associated with irrigation agriculture and include water-filled depressions on irrigated fields, wastelands,

pastures, ponds, seeps, marshes, and roadside ditches. Water in the mosquito-producing habitats was largely the result of seepage from canals and ditches, and residual irrigation water. Based on findings of these surveys, it can be assumed that mosquito problems in the project area will be intensified as additonal lands and water are devoted to irrigation agriculture unless appropriate preventive and control measures are planned and built into the project and continued as a part of regular operations. The relationships between irrigation and mosquito sources are discussed in Appendix B.

It is anticipated also that production of mosquitoes and other vectors will occur in shallow marginal areas of the reservoirs, particularly those areas which have emergent vegetation and flotage and are protected from wave action. Production of mosquitoes and other vectors in habitats associated with the reservoirs could seriously deter the proper utilization of recreational and public use areas along the shores of the reservoirs. General information concerning reservoir preparation, maintenance, and water level management in relation to mosquito prevention and control is presented in Appendix C.

Responsibility for Vector Control

Responsibility for vector prevention and control is normally associated with land ownership or operating rights. Therefore, the agency, group, or individuals responsible for various aspects of the proposed project should be prepared to accept full responsibility for the prevention and control of vector problems resulting from the design, construction, operation, or maintenance of the project.

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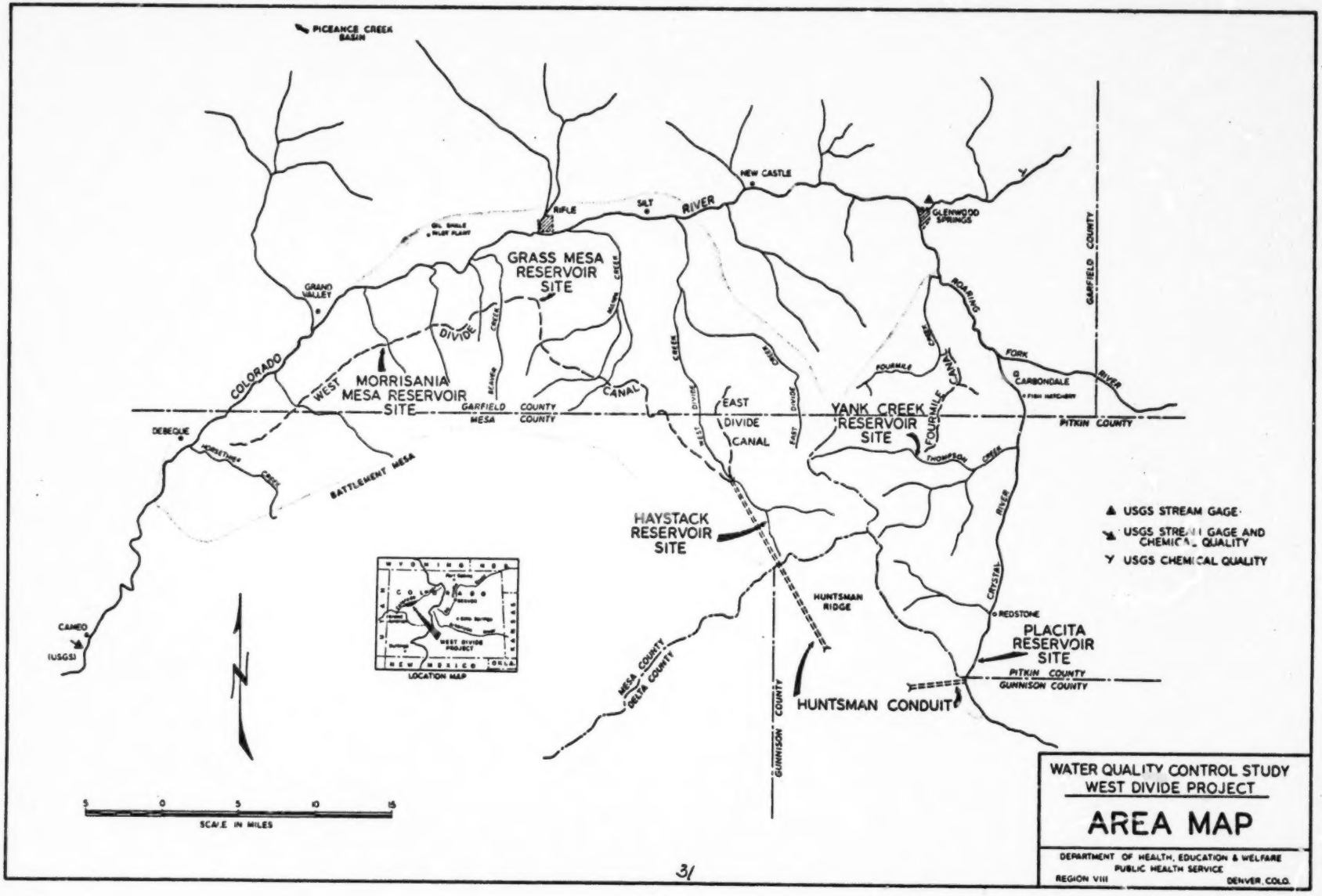
APPENDIX A

ANNUAL WEIGHTED AVERAGES - COLORADO RIVER ABOVE GLENWOOD SPRINGS AND AT CAMEO COLORADO

Water Year	Discharge Mean (cfs)	Ca	Mg	Na	HCO_3	SO_4	Cl	TDS		Hardness
		mg/l						mg/l	tons/day	
Above Glenwood Springs										
1942	2688	39	8.1	29	98	56	39	233	1690	131
1943	2455	39	9.0	33	98	63	43	249	1650	134
1944	2080	40	9.0	36	103	61	49	259	1450	137
1945	2372	38	8.5	31	95	58	42	238	1500	130
1946	2149	41	9.2	33	99	64	46	257	1490	140
1947	3124	35	7.9	27*	93	49	34	210	1770	120
1948	2670	38	7.8	31*	100	54	39	228	1640	127
1949	2829	39	8.5	28*	102	57	37	232	1770	132
1950	2038	45	10	38*	111	68	52	279	1530	154
1951	2552	39	8.8	30	102	56	41	245	1690	134
1952	3362	40	8.5	25	106	56	33	236	2140	135
1953	2194	46	10	37	112	68	52	288	1710	156
1954	1224	58	11	61	136	102	78	401	1320	190
1955	1418	58	10	50	121	93	73	372	1420	186
1956	2024	51	9.7	35	116	77	49	299	1630	167
1957	3327	42	7.1	25	107	53	32	237	2130	134
At Cameo										
1934	2568	60	16	98	138	120	134	513	3560	216
1935	3952	48	11	55	122	78	75	343	3660	165
1936	5010	44	10	52	114	74	69	323	4370	151
1937	3505	55	14	77	134	103	105	442	4180	194
1938	5610	49	11	59	122	84	79	355	5380	168
1939	3733	52	13	70	128	95	95	411	4140	183
1940	2753	57	14	84	137	110	115	467	3470	200
1941	4089	52	12	68	129	92	91	398	4390	179
1942	4986	51	12	66	130	90	90	391	5260	176
1943	3985	51	12	68	130	91	91	392	4220	176
1944	3740	54	12	68	140	89	86	380	3840	184
1945	4085	51	14	63*	141	90	79	377	4160	184
1946	3558	51	15	67*	132	92	93	395	3790	188
1947	5175	47	11	50*	128	73	63	318	4440	162
1948	4580	50	13	59*	128	87	77	360	4450	178
1949	4614	52	12	58*	146	83	68	358	4460	179
1950	3532	56	14	76*	147	102	97	428	4070	197
1951	4020	51	13	64*	128	88	88	389	4220	180
1952	5689	54	13	51*	154	80	63	360	5530	188
1953	3554	58	12	72	144	98	97	434	4160	194
1954	2144	74	16	116	171	145	152	618	3580	250
1955	2730	71	12	92	163	121	119	520	3830	226
1956	3328	58	13	71	140	101	96	432	3880	198
1957	5819	50	9.6	47	133	67	62	332	5220	164

*These values contain both sodium and potassium
Source: USGS Data



WATER QUALITY CONTROL STUDY
WEST DIVIDE PROJECT

AREA MAP

DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VIII DENVER, COLO.